RD-29,472-2 IS A DIVISION OF RD-29,472

Claims

[c1] 1. A cross current control system for multiple, parallel-coupled power converters, the cross current control system comprising:
common mode chokes, each coupled to a respective power converter;
local cross current detectors, each configured for obtaining common mode cross currents from a respective output line of a respective power converter;
local cross current feedback controllers, each configured for receiving the common mode cross currents from respective local cross current detectors, calculating a resultant cross current, and generating a local feedback control signal; and
local converter controllers, each configured for using a respective local feedback control signal to drive the respective power converter in accordance with a coordinated switching pattern with respect to the other power converters.

[c2] 2. The system of claim 1, further comprising a global feedforward controller configured for detecting switching patterns of the power converters and generating counter balance zero-sequence global feedforward control signals, wherein each of the local converter controllers is configured for using a respective global feedforward control signal to drive the respective power converter.

[c3] 3. The system of claim 2, further comprising a global feedback controller configured for receiving the common mode cross currents from the local cross current detectors, calculating a resulting global cross current, and generating global feedback control signals, wherein each of the local converter controllers is configured for using a respective global feedback control signal to drive the respective power converter.

[c4] 4. The system of claim 1, further comprising modulators, each configured for receiving a local converter controller signal from a respective local converter controller and generating a firing signal for driving a respective power converter.

[c5] 5. The system of claim 1, further comprising a global feedback controller configured for receiving the common mode cross currents from the local cross current detectors, calculating a resulting global cross current, and generating global feedback control signals, wherein each of the local converter controllers is configured for using a respective global feedback control signal to drive the respective power converter.

[c6] 6. The system of claim 1, wherein the power converters are configured to share a common DC bus.

[c7] 7. The system of claim 1, wherein the power converters comprise separate DC busses.

[c8] 8. The system of claim 1 wherein the common mode chokes comprise DC link chokes.

[c9] 9. The system of claim 1 wherein the common mode chokes comprise AC link chokes.

[c10] 10. The system of claim 9, wherein the AC link chokes comprise discrete magnetic chokes.

[c11] 11. The system of claim 9, wherein the AC link chokes comprise integrated magnetic chokes.

[c12] 12. The system of claim 11, wherein each integrated magnetic choke comprises an integrating magnetic structure coupling a three phase common mode choke and a three phase differential mode choke.

[c13] 13. The system of claim 12, wherein each integrating magnetic structure comprises a common mode core and a differential mode core with the common mode core comprising a higher permeability material than the differential core.

[c14] 14. The system of claim 13, wherein the common mode core comprises a closed rectangular core wound with three common mode coils, one for each phase, and wherein the differential mode core comprises an E core wound with a respective differential mode coil on each leg, the legs of the E core facing the closed rectangular core and sharing a part of magnetic flux path of the closed rectangular core.

[c15] 15. The system of claim 13, wherein the common mode core comprises a top closed rectangular core wound with three common mode top coils and a bottom closed rectangular core wound with three common mode bottom coils, and wherein the differential mode core comprises three posts with a respective differential mode coil on each post, the three posts arranged between the top and bottom closed rectangular cores and sharing a part of top and bottom rectangular magnetic flux paths.

[c16] 16. The system of claim 12, wherein the respective phases of the three phase common mode choke and three phase differential mode choke are connected in series.

[c17] 17. The system of claim 11, wherein the integrated magnetic choke comprises an integrated magnetic structure coupling a single phase common mode choke and a single phase differential mode choke.

[c18] 18. The system of claim 17, wherein the integrating magnetic structure comprises a common mode core and a differential mode core with the common mode core comprising a higher permeability material than the differential core.

[c19] 19. The system of claim 18, wherein the common mode core comprises a closed rectangular core wound with two common mode coils, and wherein the differential mode core comprises a U core wound with two differential mode coils on each leg, the legs of the U core facing the closed rectangular core and sharing a part of magnetic flux path of the closed rectangular core.

[c20] 20. The system of claim 18, wherein the common mode core comprises a top closed rectangular core wound with two common mode top coils and a bottom closed rectangular core wound with two common mode bottom coils, and wherein the differential mode core comprises two posts with a differential mode coil on each post, the two posts arranged between the top and bottom closed rectangular cores and sharing a part of top and bottom rectangular magnetic flux paths.

[c21] 21. The system of claim 17, wherein the single phase common mode choke and single phase differential mode choke are connected in series.

[c22] 22. A cross current control system for multiple, parallel-coupled power converters, the cross current control system comprising:
common mode chokes, each coupled to a respective power converter and comprising an integrated magnetic AC link choke;
local cross current detectors, each configured for obtaining a common mode cross current from a respective output line of a respective power converter;
local cross current feedback controllers, each configured for receiving the common mode cross currents from respective local cross current detectors, calculating a resultant cross current, and generating a local feedback control signal;
a global feedforward controller, configured for detecting switching patterns of the power converters and generating counter balance zero-sequence global feedforward control signals; and
local converter controllers, each configured for using a respective local feedback control signal and a respective global feedforward control signal to drive the respective power converter in accordance with an interleaved switching pattern with respect to the other power converters.

[c23] 23. The system of claim 22, further comprising a global cross current feedback controller, configured for receiving the common mode cross currents from the local cross current detectors, calculating a resulting global cross current, and generating global feedback control signals, wherein each of the local converter controllers is configured for using a respective global

feedback control signal to drive the respective power converter.

[c24] 24. The system of claim 22, further comprising modulators, each configured for receiving a local converter controller signal from a respective local converter controller and generating a firing signal for driving a respective power converter.

[c25] 25. The system of claim 22, wherein the integrated magnetic choke comprises an integrating magnetic structure coupling a three phase common mode choke and a three phase differential mode choke.

[c26] 26. The system of claim 25, wherein the integrating magnetic structure comprises a common mode core and a differential mode core with the common mode core comprising a higher permeability material than the differential core.

[c27] 27. The system of claim 26, wherein the common mode core comprises a closed rectangular core wound with three common mode coils, one for each phase, and wherein the differential mode core comprises an E core wound with a respective differential mode coil on each leg, the legs of the E core facing the closed rectangular core and sharing a part of magnetic flux path of the closed rectangular core.

[c28] 28. The system of claim 26, wherein the common mode core comprises a top closed rectangular core wound with three common mode top coils and a bottom closed rectangular core wound with three common mode bottom coils, and wherein the differential mode core comprises three posts with a respective differential mode coil on each post, the three posts arranged between the top and bottom closed rectangular cores and sharing a part of top and bottom rectangular magnetic flux paths .

[c29] 29. The system of claim 22, wherein the integrated magnetic choke comprises an integrated magnetic structure coupling a single phase common mode choke and a single phase differential mode choke.

[c30] 30. The system of claim 29, wherein the integrating magnetic structure comprises a common mode core and a differential mode core, the common mode core comprising a higher permeability material than the differential core.

[c31] 31. A cross current control system for multiple, parallel-coupled power converters, the cross current control system comprising:
common mode chokes, each coupled to a respective power converter ;
local cross current detectors, each configured for obtaining a common mode cross current from a respective output line of a respective power converter;
local cross current feedback controllers, each configured for receiving the common mode cross currents from respective local cross current detectors, calculating a resultant cross current, and generating a local feedback control signal;
a global feedforward controller configured for detecting switching patterns of the power converters and generating counter balance zero-sequence global feedforward control signals;
a global cross current feedback controller configured for receiving the common mode cross currents from the local cross current detectors, calculating a resulting global cross current, and generating global feedback control signals; and
local converter controllers, each is configured for using a respective local feedback control signal, a respective global feedback control signal and a respective global feedforward control signal, to drive the respective power converter in accordance with an interleaved switching pattern with respect to the other power converters.

[c32] 32. The system of claim 31 wherein the common mode choke comprises an AC link choke.

[c33] 33. The system of claim 32, wherein the AC link choke comprises an integrated magnetic choke.

[c34] 34. The system of claim 33, wherein the integrated magnetic choke comprises an integrating magnetic structure coupling a three phase common mode choke and a three phase differential mode choke.

[c35] 35. The system of claim 34, wherein the integrating magnetic structure comprises a common mode core and a differential mode core with the common mode core comprising a higher permeability material than the differential core.

[c36] 36. The system of claim 35, wherein the common mode core comprises a closed rectangular core wound with three common mode coils, one for each phase, and wherein the differential mode core comprises an E core wound with a respective differential mode coil on each leg, the legs of the E core facing the closed rectangular core and sharing a part of magnetic flux path of the closed rectangular core.

[c37] 37. The system of claim 35, wherein the common mode core comprises a top closed rectangular core wound with three common mode top coils and a bottom closed rectangular core wound with three common mode bottom coils, and wherein the differential mode core comprises three posts with a respective differential mode coil on each post, the three posts arranged between the top and bottom closed rectangular cores and sharing a part of top and bottom rectangular magnetic flux paths.

[c38] 38. The system of claim 34, wherein the respective phases of the three phase common mode choke and three phase differential mode choke are connected in series.

[c39] 39. The system of claim 33, wherein the integrated magnetic choke comprises an integrating magnetic structure coupling a single phase common mode choke and a single phase differential mode choke, the single phase common mode and differential mode chokes being connected in series.

[c40] 40. The system of claim 39, wherein the integrating magnetic structure comprises a common mode core and a differential mode core, the common mode core comprising a higher permeability material than the differential core.

[c41] 41. The system of claim 40, wherein the common mode core comprises a closed rectangular core wound with two common mode coils, and wherein the differential mode core comprises a U core wound with two differential mode coils on each leg, the legs of the U core facing the closed rectangular core and sharing a part of magnetic flux path of the closed rectangular core.

[c42] 42. The system of claim 40, wherein the common mode core comprises a top closed rectangular core wound with one common mode top coil and a bottom closed rectangular core wound with one common mode bottom coil, and wherein the differential mode core comprises two posts with a differential mode coil on each post, the two posts arranged between the top and bottom closed rectangular cores and sharing a part of top and bottom rectangular magnetic flux paths.

[c43] 43. An integral choke assembly comprising:
a common mode choke comprising a common mode core wound with at least two common mode coils; and
a differential mode choke comprising a differential mode core wound with at least one differential mode coil,
wherein the common and differential mode choke cores are configured so that at least one magnetic flux path is shared by magnetic flux generated by common mode coils and differential mode coils.

[c44] 44. The assembly of claim 43 wherein the common mode coils and differential mode coils are connected in series.

[c45] 45. The assembly of claim 43, wherein the common mode core comprises a higher permeability material than the differential mode core.

[c46] 46. The assembly of claim 43, wherein the common mode core comprises a closed rectangular core wound with three common mode coils, one for each phase, and wherein the differential mode core comprises an E core wound with a respective differential mode coil on each leg, the legs of the E core facing the closed rectangular core and sharing a part of magnetic flux path of the closed rectangular core.

[c47] 47. The assembly of claim 46, wherein the respective phases of the common mode coils and differential mode coils are connected in series.

[c48] 48. The assembly of claim 43, wherein the common mode core comprises a top closed rectangular core wound with three common mode top coils and a bottom closed rectangular core wound with three common mode bottom coils, and wherein the differential mode core comprises three posts with a respective differential mode coil wound on each post, the posts being arranged between the top and bottom closed rectangular cores and sharing a part of top and bottom rectangular magnetic flux paths.

[c49] 49. The assembly of claim 43, wherein the common mode core comprises a closed rectangular core wound with two common mode coils, and wherein the differential mode core comprises a U core wound with two differential mode coils on each leg, the legs of the U core facing the closed rectangular core and sharing a part of magnetic flux path of the closed rectangular core.

[c50] 50. The assembly of claim 43, wherein the common mode core comprises a top closed rectangular core wound with one common mode top coil and a bottom closed rectangular core wound with one common mode bottom coil, and wherein the differential mode core comprises two posts with a differential mode coil on each post, the two posts arranged between the top and bottom closed rectangular cores and sharing a part of top and bottom rectangular magnetic flux paths.

[c51] 51. An integral choke assembly comprising:
a three phase common mode choke comprising a common mode core, wherein the common mode core comprises closed rectangular core wound with three common mode coils, one for each phase; and
a three phase differential mode choke comprising a differential mode core, wherein the differential mode core comprises an E core wound with a respective differential mode coil on each leg, the legs of the E core facing the closed rectangular core and sharing a part of magnetic flux path of the closed rectangular core.

[c52] 52. The assembly of claim 51, wherein the respective phases of the common mode coils and differential mode coils are connected in series.

[c53] 53. An integral choke assembly comprising:
a three phase common mode choke comprising a common mode core, wherein the common mode core comprises a top closed rectangular core wound with three common mode top coils and a bottom closed rectangular core wound with three common mode bottom coils; and
a three phase differential mode choke comprising a differential mode core, wherein the differential mode core comprises three posts, with a respective differential mode coil on each post, the three posts arranged between the top and bottom closed rectangular cores and sharing a part of top and bottom rectangular magnetic flux paths.

[c54] 54. The assembly of claim 53, wherein the respective phases of the common mode coils and differential mode coils are connected in series.

[c55] 55. An integral choke assembly comprising:
a single phase common mode choke comprising a common mode core, wherein the common mode core comprises a closed rectangular core wound with two common mode coils; and
a single phase differential mode choke comprising a differential mode core, wherein the differential mode core comprises a U core wound with two differential mode coils on each leg, the legs of the U core facing the closed rectangular core and sharing a part of magnetic flux path of the closed

rectangular core.

[c56] 56. The assembly of claim 55, wherein the single phase common mode and differential mode chokes are connected in series.

[c57] 57. An integral choke assembly comprising:
a single phase common mode choke comprising a common mode core, wherein the common mode core comprises a top closed rectangular core wound with one common mode top coil and a bottom closed rectangular core wound with one common mode bottom coil; and
a single phase differential mode choke comprising a differential mode core, wherein the differential mode core comprises two posts with a differential mode coil on each post, the two posts arranged between the top and bottom closed rectangular cores and sharing a part of top and bottom rectangular magnetic flux paths.

[c58] 58. The assembly of claim 57, wherein the single phase common mode and differential mode chokes are connected in series.

[c59] 59. A method of controlling cross-current through multiple, parallel-coupled power converters, comprising:
providing common mode chokes, each coupled to a respective power converter;
obtaining common mode cross currents from output lines of the power converters; and
for each respective power converter,
calculating a resultant cross current by using the respective common mode cross currents,
generating a local feedback control signal by using the resultant cross current,
driving the respective power converter by using the respective local feedback control signal in accordance with a coordinated switching pattern with respect to the other power converters.

[c60] 60. The method of claim 59, further comprising detecting switching patterns of the power converters and generating counter balance zero-sequence global feedforward control signals associated with respective power converters, wherein driving the respective power converter comprises using the respective global feedforward control signal.

[c61] 61. The method of claim 60, further comprising obtaining common mode cross currents from output lines of the power converters; calculating a resulting global cross current; and generating global feedback control signals, wherein driving the respective power converter comprises using the respective global feedback control signal.

[c62] 62. The method of claim 59, further comprising obtaining common mode cross currents from output lines of the power converters; calculating a resulting global cross current, and generating global feedback control signals associated with respective power converters wherein driving the respective power converter comprises using the respective global feedback control signal.

[c63] 63. The method of claim 59 wherein providing common mode chokes comprises providing DC link chokes.

[c64] 64. The method of claim 59 wherein providing the common mode chokes comprises providing AC link chokes.

[c65] 65. The method of claim 64, wherein providing AC link chokes comprises providing discrete magnetic chokes.

[c66] 66. The method of claim 65, wherein providing the AC link chokes comprises providing integrated magnetic chokes.

[c67] 67. A method for controlling a power converter comprising:
providing an integrated magnetic AC link common mode choke coupled to the power converter;
obtaining common mode currents from respective output lines of the power converter;

generating a feedback control signal; and

driving the power converter by using the feedback control signal.